Surveillance of habitats and plant diversity indicators across a regional gradient in the Iberian Peninsula

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ABSTRACT

Located in the west of the Mediterranean and with high environmental heterogeneity, the Iberian Peninsula represents a challenging region for designing and implementing observation systems for landscape, habitat and species diversity indicators. Within the framework of a project designed to set up a European Biodiversity Observation Network (EBONE), a standardized protocol for field survey was used in pilot sites located across a major gradient in Portugal and Spain. Results are presented and compared to assess the efficiency of the method in detecting patterns along this gradient. These sites represent different types of Iberian landscapes selected using a stratified random procedure implemented in the Madrid province (Spain) and in the north of Portugal. Species and habitat richness and diversity (as well as their components) are compared in their relation to environmental gradients and survey area. Results from spatial analyses of landscape heterogeneity are also presented and discussed in relation to appropriate indicators. The implications for setting up cost-efficient observation schemes that capture the key indicators effectively are discussed. Perspectives for integration with complementary monitoring schemes targeted at key species, habitat and landscape indicators are also discussed in order to optimize the power and efficiency of these observation networks.

1. Introduction

In an era of global environmental change, the need for accurate estimates of biodiversity loss around the world has become a core objective in order to meet the international conservation goals for 2020 (European Commission, 2011). Previous estimates to tackle the 2010 targets have been based on local measures and on the use of the Streamlining European Biodiversity Indicators (SEBI). However a lack of harmonization has been noted in the surveys behind several estimates (Bunce et al., 2008; Lengyel et al., 2008; Schmeller, 2008). Therefore, so far only partial estimates have been obtained which suggest that rapid biodiversity loss is actually ongoing, but the extent of the decline is unknown (Scholes et al., 2008; Butchart et al., 2010; Pereira et al., 2010).

Designing the scientific and institutional framework as well as the tools to support such global assessment is at the core of several initiatives at global and sub-global level e.g. GEO BON, Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) or the European Union (EU) funded European Biodiversity Network (EBONE) project (Halada et al., 2009; Larigauderie and Mooney, 2010; GEO BON, 2011). The objective of the latter is the provision of a sound scientific basis for the production of statistical estimates of stock and change of key indicators that can then be interpreted by policy makers responding to EU Directives regarding threatened ecosystems and species (Metzger et al., 2010). The main output was the development of a system for estimating past change but also for forecasting and testing policy options and supporting the design of mitigating management strategies for threatened ecosystems and species. In this context EBONE has developed a European system for recording habitats and associated data suitable for *in situ* recording (Bunce et al., 2011) which also allows exchange and integration between

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existing national projects. The protocol includes the whole land surface and is exchangeable with the FAO (Food and Agriculture Organization) Land Cover Classification System (Di Gregorio and Jansen, 2000).

Among the relevant achievements from EBONE has been an evaluation of the Environmental Stratification of Europe (EnS; Metzger et al., 2005) as a method for selection of stratified samples, through a statistical comparison with national environmental classifications such as the Great Britain Countryside Survey (Firbank et al., 2003; Sheail and Bunce, 2003), the Swedish National Inventory of Landscapes (Esseen et al., 2006), the Austrian Survey of Agricultural Landscapes (Wrbka et al., 1999) and the Spanish Survey of Habitats (Elena-Rosselló et al., 1997, 2005). In general, the EnS was found to be comparable with regional stratifications and to resolve border effects where divergent environmental conditions are combined into dominant strata (Ortega et al., 2012). The test of a Europe-wide sampling strategy based on the EnS and of a survey protocol for habitats and species based on life forms and general habitat categories (GHCs) has been achieved in EBONE (Bunce et al., 2008; Hazeu et al., 2011). This protocol has been tested in the field in contrasting environments, from boreal conifer forests to hot deserts, but a formal test on its effectiveness in the assessment of species and habitat diversity patterns across a major environmental gradient has not yet been carried out. In addition, its effectiveness in recording relevant indicators has not been determined.

The Iberian Peninsula is an important reservoir of European biodiversity (Morillo and Gomez-Campo, 2000), and is usually included in the "Mediterranean Region" hotspot of global biodiversity (Myers et al., 2000). However, the peninsula also presents challenges for setting up an ecological monitoring program due to its high environmental and social-ecological heterogeneity (Rey-Benayas and Scheiner, 2002; Rescia et al., 2008). Previous assessment and monitoring programmes in Spain and Portugal have ranged from national forest inventories and land cover mapping to landscape inventories from both structural (e.g. Elena-Rosselló et al., 1997, 2005 in Spain; and Caetano et al., 2008, in Portugal) and functional (e.g. Alcaraz-Segura et al., 2009) perspectives. However, due to their specific goals these approaches have not been able to identify habitat and biodiversity indicators with the enough detail to support regional management needs whilst meeting the requirements of national and international reporting, e.g. on the application of the EU Habitats Directive and the implementation of the Natura 2000 network (Evans, 2006). There is therefore a requirement to test a common Iberian system for habitat and biodiversity monitoring that can contribute to cross-border management and policy, as well as to international goals.

This paper therefore presents and discusses results of a pilot survey of habitats and biodiversity across a major environmental gradient in the Iberian Peninsula, including test sites in Spain and Portugal. The pilot involved the selection and survey of 10 sites with landscape mosaics in two regions of the peninsula with contrasting climates, vegetation, land uses and landscape structure. Data on habitat and plant diversity data from those 10 site were used to address the following three objectives: (i) to assess the effectiveness of the EBONE protocol in identifying indicators of habitats and plant biodiversity at the landscape scale; (ii) to test possible effects of survey area on the effectiveness of the protocol, and to discuss implications for improving the efficiency of the approach; and (iii) to describe and analyse habitat and biodiversity indicators across a major environmental and social-ecological gradient in the Iberian Peninsula (Metzger et al., 2005, 2010). Finally, guidelines are proposed for the design and implementation of an Iberian monitoring program for habitats and biodiversity, as a regional contribution to a pan-European observation network.

2. Methods

2.1. Test regions and sites

The sampling strategy and field methodology for surveillance of habitats and plant species richness used was described by Bunce et al. (2008, 2011). The method was tested in 10 sites across a major environmental gradient in the Iberian Peninsula, five of which were located in Spain and the remaining five in Portugal. These sites were selected within two contrasting test regions: the Madrid province (NUTS code ES30) and the North of Portugal (NUTS code PT11). Inside each of these two regions, five INSPIRE 1 km^2 grid cells were selected under a stratified random sampling design based on the EnS (Metzger et al., 2005). The underlying environmental gradient discriminating the set of 10 sites is related to decreasing temperatures and continental influence on the gradient from the southern Mediterranean towards the northern and mountainous Mediterranean areas and further into the Atlantic ("Lusitanian") zone in the north-west of the Peninsula (Fig. 1). This climatic gradient has been summarized in the system used for stratifying the allocation of samples (Metzger et al., 2005).

The EnS identifies relatively homogeneous regions in Europe suitable for strategic random sampling of ecological resources (Metzger et al., 2010). It provides a generic classification that can be adapted for a specific objective, whilst providing suitable zones for environmental reporting (Hazeu et al., 2011). The EnS was created using tried-and-tested statistical clustering procedures on 20 primary physical environmental variables. These were (1) climate variables from the Climatic Research Unit (CRU) TS1.2 dataset (Mitchell et al., 2004); (2) elevation data from the United States Geological Survey HYDRO1k digital terrain model; and (3) indicators for oceanicity and northing. Principal components analysis (PCA) was used to compress 88% of the variation of these 20 environmental characteristics into three dimensions, which were subsequently clustered using the Iterative Self-Organizing Data Analysis (ISODATA) clustering routine. The scores of each grid cell along these three PCA dimensions therefore represent key environmental features in relation to the main gradients across Europe (temperature for PCA1, oceanicity for PCA2, and precipitation for PCA3; Metzger et al., 2005). The classification procedure has been described in detail by Metzger et al. (2005).

The EnS comprises 84 strata, aggregated into 13 environmental zones (EnZs) with a data resolution of 1 km^2. The Iberian Peninsula has six EnZs and four are included in the test areas. The Spanish test region was in the Madrid province with an area of 8.021 km^2. Five sites were randomly selected within strata, using an area-proportional allocation, three in the number 1 stratum of the Mediterranean South zone (MDS1) and two in the number 6 stratum of the Mediterranean North zone (MDN6) of the EnS. In Portugal, the test region was in the north of the country with an area of 21,278 km^2. Five sites were also selected randomly within strata, in the same area-proportional way, two in the number 4 stratum of the Lusitanian zone (LUS4), one in the number 1 stratum of the same zone (LUS1), one in the number 5 stratum of the Mediterranean Mountains zone (MDM5), and finally one in the number 3 stratum of the Mediterranean North zone (MDN3). The distribution of the sites in these strata and EnZs is shown in Fig. 1. This sampling design tries to simulate a basic network Nomenclature of Territorial Units for Statistics (NUTS) area that could be proposed to include in a pan-European biodiversity observation network.

Near Madrid, the gentle relief together with the dry Mediterranean climate has produced a dominance of extensive land uses with low spatial heterogeneity and coarse-grained landscape mosaics. Therefore, in the five Spanish sites 1 km^2 grid cells (from the INSPIRE grid used for the EnS of Metzger et al., 2005) were used as survey units, as recommended by Bunce et al. (2008).

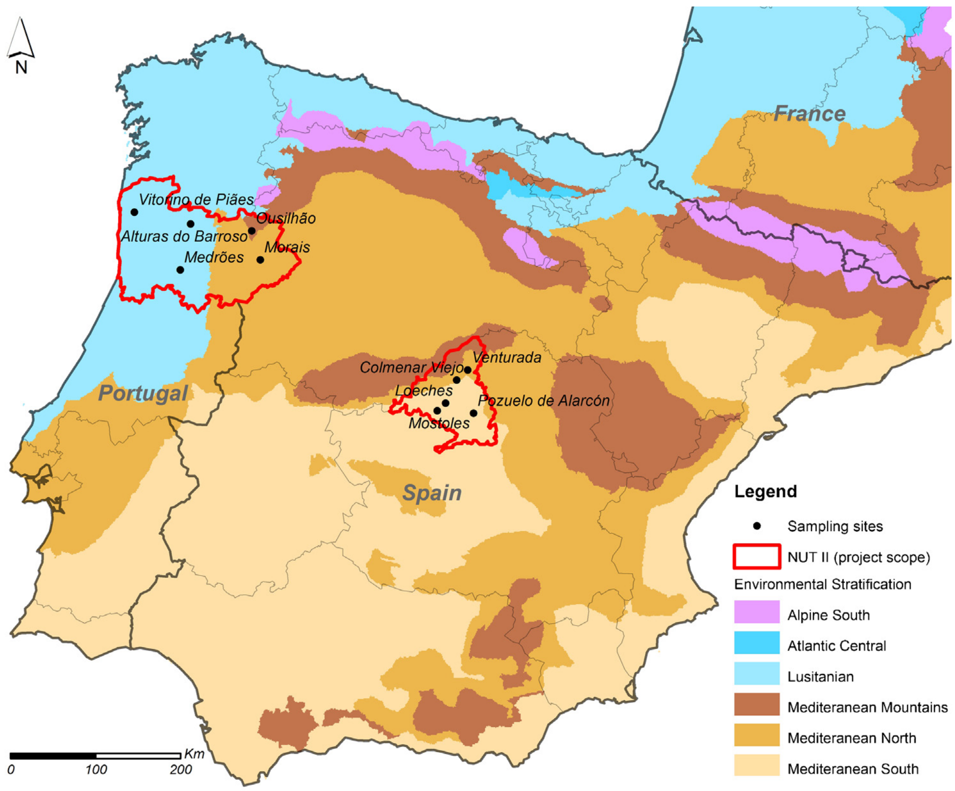

Fig. 1. Representation of the selected sampling sites within the climatic gradient of the Environmental Stratification of Europe aggregated by environmental zones (Metzger et al., 2005). Thin grey lines indicate NUTS-II regions in the Iberian Peninsula. Thick lines indicate study regions in northern Portugal and central Spain. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of the article.)

Conversely, in the North of Portugal, the complex physiography and terrain, with a humid Atlantic climate, together with a long history of intensive land use, has led to fine-grained landscapes. For the five Portuguese sites a survey area of 0.25 km^2 was therefore used (based on a 0.5 km × 0.5 km grid cell resulting from a disaggregation of the INSPIRE 1 km^2 grid cells). This cell size follows previous examples under comparable conditions elsewhere (Cooper et al., 2009; Rogers et al., 2012). This approach allowed the field survey be adapted to the features of the test landscapes whilst providing an opportunity to address the possible consequences of this procedure on the overall effectiveness of the method.

2.2. Field surveys for habitats and plant diversity

In each site, all GHCs were recorded and mapped, including linear features, following the EBONE protocol as described in Bunce et al. (2011). The basis for the GHC typology is the classical classification of plant life forms devised by Raunkiaer in the early 20th century. These life forms (from annuals and herbaceous perennials, to tall shrubs and trees) transcend the description of species. They are based on the scientific hypothesis that habitat structure is related to the environment. The system defines 160 general habitat categories (GHCs), as described by Bunce et al. (2011). Variation within a given GHC is then expressed by environmental and global qualifiers, which are combinations of soil humidity, nutrient status, acidity and other habitat characteristics. Important additional information is given by adding codes from predefined lists of qualifiers describing human management and other site features. Finally full lists of GHCs in each unit are added, together with information on dominant species. In this particular study, these variations are expressed as diversity of "habitat types".

Vegetation plots to estimate plant diversity in GHCs were selected randomly within each GHC, following three criteria: (i) one vegetation plot per GHC or linear element category and per environmental qualifier or dominant species; (ii) no vegetation plots in urban, water bodies too deep to sample or dangerous terrain; (iii) if there were more than one element of a certain GHC, than select randomly one of them and select also randomly the location of the plot inside the GHC avoiding edge effect with a buffer of at least 3 m (Bunce et al., 2011). The size and shape of vegetation plots are shown in Table 1. Vascular plants were used as a focal group since they are considered as suitable indicators of biodiversity and are relatively rapid to survey and identify. Also, as primary producers they play a critical role in supplying ecosystem goods and services, and are the single most important group of organisms in shaping habitats for other species (Lughadha et al., 2005; Pereira and Cooper, 2006). Field work for habitat recording and vegetation plots extended for two or three visits per site depending on the spatial heterogeneity and species diversity.

2.3. Data analysis

With the collected data, three type of analysis were carried out. First, for the landscape spatial analysis, landscape metrics were calculated to summarize spatial patterns of habitats and main landscape traits of each surveyed grid cell. The number of GHCs, number of patches, mean patch size, patch density and GHC Shannon diversity were calculated at landscape level. Together, these metrics cover several key features of landscape heterogeneity, from composition to configuration. In order to compare landscape metrics across sites, each Spanish site was divided into four zones of 0.25 km^2. The number of Corine Land Cover Map level 3 classes in each site was also analysed in the same way in order to assess the effectiveness of the EBONE protocol in identifying indicators of habitats at the landscape scale.

Table 1
Vegetation plots characteristics (adapted from Bunce et al., 2011).

Code	Name	Where	Size	No. per site
X	Areal plots	Centroid at random points in polygons	10 m × 10 m	Variable
L	Linears plots	Centroid at random along linear features	10 m × 1 m	Variable

Plant species richness analyses were also performed, using all vegetation plots collected during the survey to test for differences in the relative size of biodiversity pools (and their additive alpha and beta components) for each site and environmental strata as well as to assess the relative effectiveness of the implemented sampling strategies. This analysis was aimed to address the possible area effects on the effectiveness of the field protocol. Finally, an EnS-based evaluation was done by plotting and comparing the contrasts between sites in the different environmental strata.

The effectiveness of the field surveys to capture the patterns of species diversity was assessed through randomized species accumulation curves, or sample-based rarefaction curves in the terminology of Gotelli and Colwell (2001), using EstimateS v8.2.0 (Colwell, 2009). These curves are calculated with 95% confidence intervals, using the mathematical approach proposed by Colwell et al. (2004), and their asymptotic shape is considered indicative of survey effectiveness (Magurran, 2004). Specifically, the total number of species was used in each of the pooled samples as a preferential estimator to establish the comparisons between sites. As richness estimation option, EstimateS computes the asymptotic function most commonly used, the Michaelis–Menten function (Colwell and Coddington, 1994) and Bootstrap incidence-based estimator of species richness (Smith and van Belle, 1984) between others. In this work these estimators were used because they represented the maximum and the minimum prediction of species richness. They are therefore indicative of effectiveness, even if they are based in predictions of species not present in any sample.

3. Results

3.1. Habitat patterns across test regions and environmental strata

The mean number of GHCs per site was significantly higher in the Portuguese sites than in the Spanish sites (Mann–Whitney U test = 2.61, $p < 0.01$; Table 2). The Portuguese sites show a higher spatial heterogeneity and complexity, expressed as higher values for GHC Shannon diversity (Mann–Whitney U test = 1.98, $p < 0.05$), higher number of patches (Mann–Whitney U test = 2.61, $p < 0.01$), higher patch density (Mann–Whitney U test = 2.61, $p < 0.01$) and consequently lower mean patch size (Mann–Whitney U test = −2.61, $p < 0.01$).

When comparing the results at the environmental stratum level, dissimilarities between strata were also found, although a larger number of sampling sites would be needed to obtain a stronger statistical representation. The surveyed sites showed that the Lusitanian strata were characterized by a tendency to have a larger number of GHCs and a higher spatial heterogeneity and complexity, with more patches and a small mean patch size (Table 2). From a landscape perspective, this indicates a gradient of complexity from strata with complex, fine-grained mosaics (Lusitanian) to more homogeneous landscapes (Mediterranean South) with larger patches and fewer GHCs.

The number of land cover classes detected from the Corine Land Cover (CLC) 2006 dataset for the same sites was, as expected, significantly lower in the two regions than the number of GHCs because the map has a minimum mappable area of 25 ha as well as fewer classes (Wilcoxon matched pairs test = 2.80, $p < 0.01$) and in this case no differences were found between regions (Mann–Whitney U test = 0.52, $p = 0.60$; Table 2).

3.2. Effectiveness of the EBONE field protocol in the test regions and strata

In total, 262 species were recorded in the five Spanish sites (from 33 plots), compared with 284 species recorded in the Portuguese sites (from 47 plots), with a total of 470 species recorded in the 80 plots from all 10 sites (Fig. 2(a)). The comparison of the species accumulation curves for the five sites in the Madrid province with the values of two estimators (Bootstrap and Michaelis–Menten richness estimated for 33 plots were 300 and 352 species, respectively) suggest that the surveys captured plant diversity with effectiveness between 87% (using Bootstrap estimation) and 74% (using Michaelis–Menten estimation). For Portuguese sites, survey effectiveness ranged between 82% and 59% (Bootstrap and Michaelis–Menten richness estimated for 47 plots were 345 and 481 species, respectively). A visual comparison of species accumulation curves between Spanish and Portuguese sites revealed a more asymptotic shape of Spanish curves compared with their Portuguese counterparts, highlighting the higher heterogeneity of the latter landscapes.

The comparison of species accumulation curves per environmental stratum indicated that the two Lusitanian strata showed a tendency to accumulate species slower than the Mediterranean strata (Fig. 2(b)) a consequence of the higher mean species richness of Mediterranean plots (see below). The mean effectiveness of survey per stratum in Madrid was 85.5 ± 0.5% and 64.5 ± 4.5%, and in Portugal it was of 81 ± 2% and 47 ± 10% (using Bootstrap and Michaelis–Menten estimation, respectively).

3.3. Plant diversity patterns across the regional environmental gradient

Alpha species richness per plot and species richness of the GHC hosting the highest number of species per site exhibited significant correlations with the three first axes of the PCA of the EnS strata (Fig. 3(a)–(c); see Section 2.1). The first axis reflects a temperature gradient and was positively correlated with both variables ($R^2 = 0.45$, $F = 6.62$, $p < 0.05$ and $R^2 = 0.43$, $F = 5.91$, $p < 0.05$), therefore increasing temperatures tend to promote species richness per plot. The second and third axes, that reflect oceanicity and precipitation gradients respectively, were negatively correlated with both species richness variables ($R^2 = 0.73$, $F = 21.14$, $p < 0.01$ and $R^2 = 0.78$, $F = 28.28$, $p < 0.001$ for second axis and $R^2 = 0.62$, $F = 12.83$, $p < 0.01$ and $R^2 = 0.67$, $F = 16.13$ $p < 0.01$ for third axis), indicating that seasonal buffering by proximity to the ocean and increase of precipitation are related to lower plant species richness at the plot level.

Whilst the pattern of gamma richness per site could be influenced by the different sizes of sample units (0.25 km^2 in Portugal, against 1 km^2 in Madrid), the same does not apply to alpha richness, which was significantly higher in Madrid than in Northern Portugal (Mann–Whitney U test = 2.40, $p < 0.05$; Table 3). The additive beta component of gamma exhibited high values (between 60% and 82% of gamma richness) across all 10 sites (Fig. 3(d)), accounting for a large fraction of the total species richness and indicating a considerable floristic dissimilarity among GHCs occurring in each site. Significant differences between beta values for Spanish and Portuguese sites were found, with the latter exhibiting higher floristic dissimilarity (Mann–Whitney U test = 2.61, $p < 0.01$).

Table 2
Number of GHCs, number of Corine Land Cover 2006 (CLC) level 3 classes, number of patches, mean patch size, patch density and GHC Shannon diversity for the 10 surveyed sites. The 10 sites are identified by their environmental stratum of the EnS (Metzger et al., 2005). In order to compare landscape metrics across sites, the Spanish sites were divided into four squares of 0.25 km^2, and means are shown for each site. LUS, Lusitanian zone; MDM, Mediterranean Mountains; MDN, Mediterranean North; MDS, Mediterranean South.

	North Portugal						Central Spain					
	Alturas do Barroso LUS1	Medrões LUS4	Vitorino LUS4	Ousilhão MDM5	Morais MDN3	Sum (mean)	Colmenar MDN6	Venturada MDN6	Mostoles MDS1	Loeches MDS1	Pozuelo MDS1	Sum (mean)
GHC number	23.00	14.00	33.00	14.00	11.00	(19.00)	4.75	6.75	4.75	5.50	4.25	(5.20)
CLC number	1.00	2.00	3.00	4.00	3.00	(2.60)	1.50	3.25	2.25	1.50	2.25	(2.15)
Patch number	39.00	46.00	74.00	31.00	21.00	211 (42.2)	6.50	10.00	6.00	8.75	4.75	81 (7.20)
Mean patch size (ha)	0.64	0.50	0.35	0.81	1.19	(0.69)	5.69	4.74	4.49	3.51	5.42	(4.77)
Patch density (ha)	1.56	1.84	2.96	1.24	0.84	(1.69)	0.26	0.40	0.10	0.35	0.19	(0.26)
GHC Shannon diversity	1.73	0.84	2.59	1.35	1.71	(1.64)	0.68	1.21	0.94	1.09	0.81	(0.95)

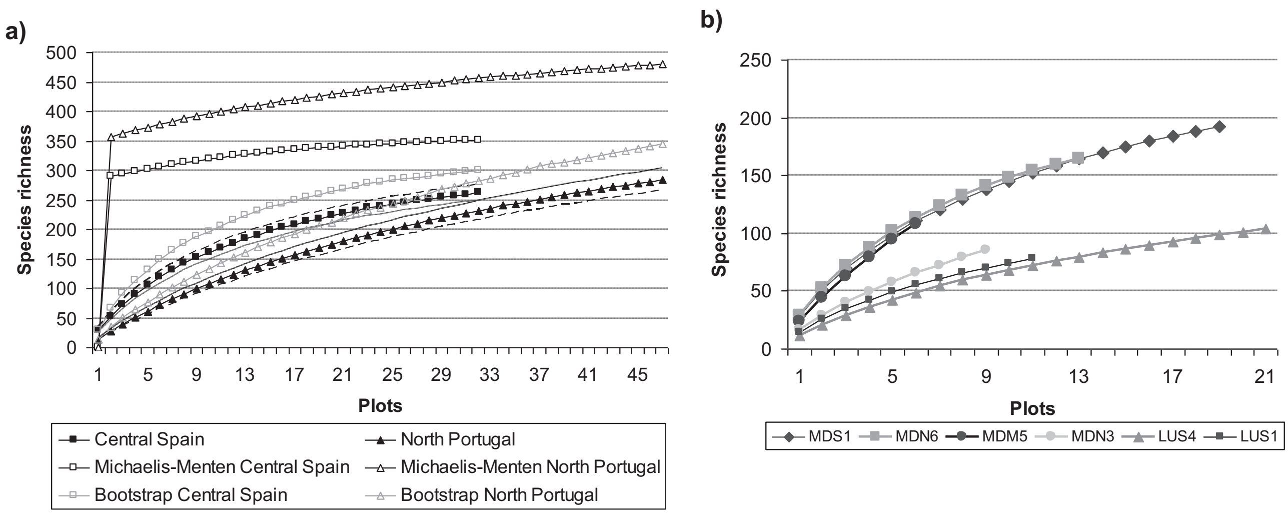

Fig. 2. Randomized accumulation curves for plant species richness in the set of 10 sites. (a) Number of species as a function of the number of plots for Spanish and Portuguese regions; a 95% confidence interval is indicated in each curve; maximum richness estimated with Bootstrap and Michaelis–Menten was 300 and 352 species, respectively, for Central Spain, and 345 and 481 species, respectively, for Northern Portugal. (b) Number of species as a function of the number of plots per environmental stratum.

Focusing on the most species rich GHC in each site, there was a tendency for species richness to exhibit variations along the same environmental gradients (Fig. 3(a)–(c)). However, not always the GHC with the most species was the one occupying a larger area in the corresponding site (Table 3). In the Spanish sites, the most species rich GHC (54 species in 10 m^2) was a linear plot of tall scrub dominated by *Quercus ilex*. This habitat was in the edges of footpaths that cross a similar GHC but with some differences in its life-form composition. The latter GHC was the one covering the largest area in that site ("Pozuelo"; Table 3), which is located in the MDS1 environmental stratum, the driest of all 10 sites, on a sandy soil and with some cattle grazing but almost semi-abandoned. Among areal plots (100 m^2), the GHC hosting the highest number of plant species was a scrub patch composed of evergreen tall shrubs, located also in the MDS1 environmental stratum. In more humid environments, such as those present in the MDN6 stratum, the most species rich GHC was similar but contained 20% less species than in MDS1. In Portugal, the number of species present in the most diverse GHC was smaller than in Spain (Mann–Whitney U test = 1.98, $p < 0.05$) (Table 3). Overall, the GHC with the most

Table 3
Relations between GHCs and plant species richness for the 10 surveyed sites: GHC occupying most area, GHC hosting most plant species, and species richness of the latter. The 10 sites are identified by their environmental stratum of the EnS (Metzger et al., 2005). LUS, Lusitanian Zone; MDM, Mediterranean Mountains; MDN, Mediterranean North; MDS, Mediterranean South. CHE/LHE, Caespitose Hemicryptophytes/Leafy Hemicryptophytes; CRO, herbaceous crop; FPH/EVR, Forest Phanerophytes Evergreen; STR, herbaceous strip; LSC, line of scrub; LTR, line of trees; MPH/EVR, Mid Phanerophytes Evergreen; TPH/EVR, Tall Phanerophytes Evergreen; THE, Therophytes; WOC, woody crop.

	North Portugal						Central Spain					
	Alturas do Barroso LUS1	Medrões LUS4	Vitorino LUS4	Ousilhão MDM5	Morais MDN3	Mean	Colmenar MDN6	Venturada MDN6	Mostoles MDS1	Loeches MDS1	Pozuelo MDS1	Mean
GHC occupying most area	CHE/LHE	WOC/SPA	CRO	CHE/LHE	FPH/EVR		THE	FPH/EVR	CRO	CRO	MPH/EVR	
GHC hosting most plant species	LTR	WOC/CHE	HST	WOC	THE		TPH/EVR	FPH/EVR	MPH/EVR	MPH/EVR	LSC	
Species richness of the GHC hosting most species	26	17	25	43	33	26.6	41	39	48	37	54	43.8
Mean alpha species richness plot	14	9	12	23	16		32	27	30	21	42	
Lineal plots number	3	1	3	2	1		2	2	3	3	1	
Areal plots number	8	7	10	4	8		4	5	2	7	4	

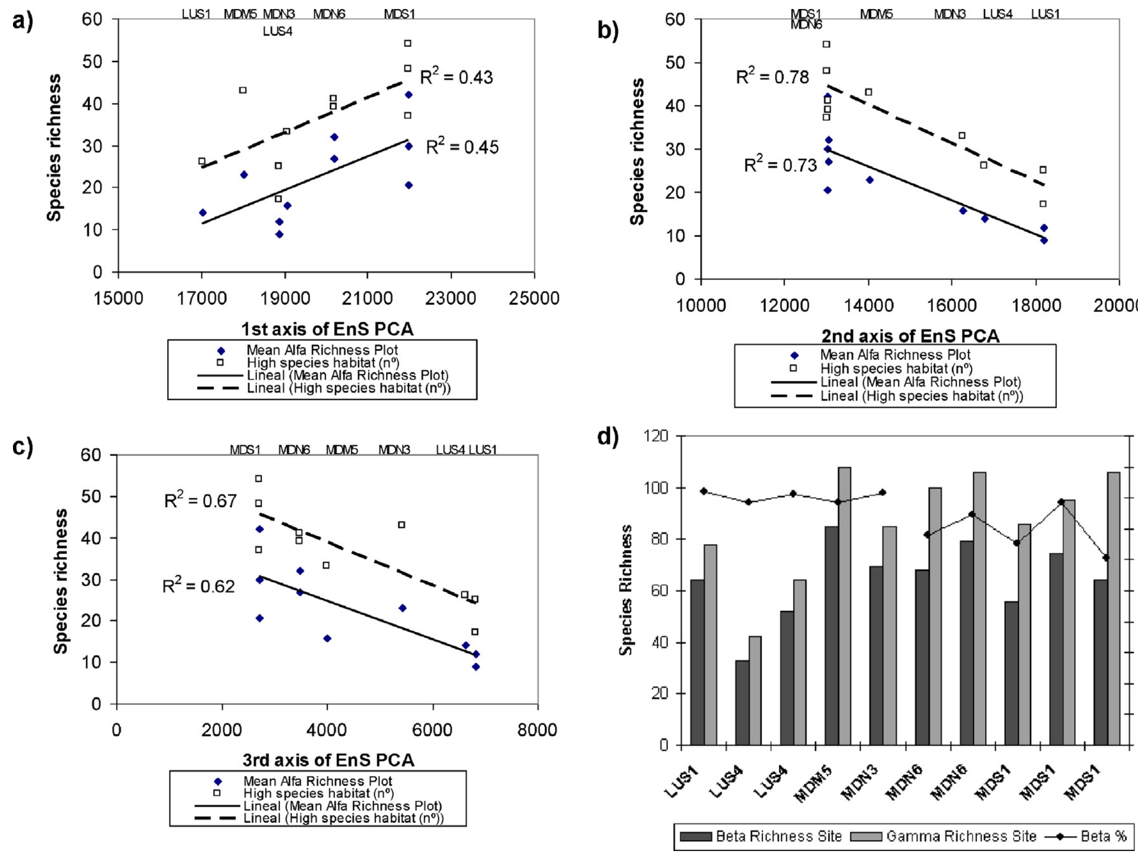

Fig. 3. Patterns and environmental correlations of plant species richness components in the 10 surveyed sites. (a–c) Variation of mean alpha richness per plot and of species richness of the most diverse habitat against the first (a), second (b) and third (c) axes of the EnS PCA. (d) Total (gamma) species richness and its beta additive component (absolute and relative values) per site. The 10 sites are identified by their environmental stratum of the EnS (Metzger et al., 2005). LUS, Lusitanian Zone; MDM, Mediterranean Mountains; MDN, Mediterranean North; MDS, Mediterranean South.

species was an old chestnut (Castanea sativa) grove (actually a woody crop in GHC terms), with 43 species in 100 m^2 (Table 3), recorded in the "Ousilhão" site (MDM5 stratum). Linear elements such as herbaceous strips and lines of trees were also among the GHCs hosting the most species per site (Table 3).

4. Discussion

4.1. Effectiveness of the EBONE protocol in the survey of habitats, species and indicators of landscape heterogeneity

Designing observation networks for the assessment of land cover, habitats and biodiversity globally will require the analysis of the performance of such networks at their several hierarchical levels and of their responses to changes of scale (Mander et al., 2003). Overall, the method used in this study (Bunce et al., 2008, 2011) was found to be successful in the survey of indicators related to habitats and plant species richness in landscape mosaics differing in composition and spatial heterogeneity (cf. Table 2). The method was able to capture the high heterogeneity of species composition across habitat types that characterizes Iberian rural landscapes (Rescia et al., 2008). Furthermore, the method was effective in capturing the richness of plant species present in the samples as derived from accumulation curves (cf. Fig. 2). Finally, the higher species richness that characterizes Mediterranean habitats and landscapes (Myers et al., 2000) was also confirmed, even although the Atlantic sites usually contained more GHCs and habitat types (cf. Tables 2 and 3 and Fig. 2).

Comparable results have been obtained in the Great Britain Countryside Survey since the 1970s (Firbank et al., 2003; Sheail and Bunce, 2003). However, further data from other regions are required to confirm these conclusions and to convert them into policy recommendations. Although with different sampling areas, resulting from an adaptation to local conditions and cost efficiency, the results indicate that in Mediterranean and Lusitanian environments the same habitat mapping protocol and vegetation sampling design works with comparable effectiveness in the estimation of biodiversity indicators. The more moderate asymptotic shape of accumulation curves for Portuguese test sites (see Fig. 2) likely results from their higher dispersion across environmental zones and strata (see Section 2.1; Metzger et al., 2005). Overall, the results therefore indicate that the EBONE methodology, supported by a statistically robust environmental stratification and suitable statistical analysis, can absorb differences in sampling areas without significant losses of effectiveness and with gains of cost-efficiency.

The landscape mosaics described in the field methodology being tested were in general agreement with the previous knowledge of each site, with the characteristic landscape features of each environmental stratum reflecting interactions with social-ecological factors and the underlying climatic gradient (see Section 2.1; Rey-Benayas and Scheiner, 2002; Metzger et al., 2010). The Portuguese sites were confirmed as fine-grain ("small-scale") landscapes (Lomba et al., 2010, 2012), with mean patch size well below one hectare (cf. Table 2) and with a dominance of crops and grasslands, with various proportions of forest. The Spanish sites were also confirmed as coarse-grain mosaics ("mid- to large-scale landscapes"), with mean patch size over five hectares and with a dominance of extensive land use e.g. annual pasture and woody crops together with open woodlands of evergreen trees. The mean number of GHCs and patches per sampled area was nearly three times higher in Portugal than in Spain. However, the Corine Land cover Classification was not able to capture the differences between Iberian regions (cf. Table 2), once again highlighting the effectiveness of the methodology being tested.

4.2. Improved efficiency of surveillance and monitoring and area effects

The key results discussed in the previous section yield two main implications. First, the Lusitanian sites of the Northern Iberian Peninsula owe their high species diversity to the high spatial heterogeneity, expressed in high diversity of habitat types and in the high levels of inter-habitat differences in species composition (i.e. the beta additive component of species richness). Conversely, the Mediterranean sites support high species richness mostly due to high values of species richness per habitat type (i.e. the alpha additive component of species richness; cf. Fig. 3). In the Iberian Peninsula, high species and land use diversity have been associated with forest cover measured at coarse scale (50 km × 50 km) by Lobo et al. (2001). Oceanicity and other climatic variables have also been related to species richness in the same sense by these authors. Rey-Benayas and Scheiner, 2002 have also related local and regional patterns of plant species richness to environmental gradients and heterogeneity at several scales in the Iberian Peninsula.

Although surveying more sites would be necessary to confirm the results, the present data suggest that high species diversity is associated with the extent of forest cover and environmental gradients at finer scales. Forest areas often contain more diverse assemblages of species (Margalef, 1974; Scheiner and Rey-Benayas, 1994), but edges are often as important. The EBONE protocol (Bunce et al., 2008, 2011) recognizes areal and linear features of landscapes as structural elements of high importance for landscape functionality. In some of the sites, linear elements contained more plant species than then open landscape (Table 3). The functional importance of linear features as corridors for individuals, seeds and genes is well known (Saunders and Hobbs, 1991), and as is their importance for biodiversity in Mediterranean areas (García Del Barrio et al., 2006). In other environments, linear features such as hedgerows share many species with the nearby woodland habitats (McCollin et al., 2000) and also contain "weedy plants" that invade the neighbouring woods (Honnay et al., 2002). Riparian zones are also known for their richness and for the invasive capacity of their species (Planty-Tabacchi et al., 1996). In addition, many of the interactions between the various communities of the landscape are reflected in the contact zones between them. The most dynamic zone for "species flow" is reported to be where linear elements provide refuges for plant species of enclosed habitats (Fagan and Cosner, 1999). In many northern European agricultural landscapes, field margins comprise the majority of semi-natural habitats (Marshall and Moonen, 2002). In areas of intensive farming the majority of native species are found in small woodland patches (Dumortier et al., 2002; Lomba et al., 2010, 2011) and in hedgerows around fields (Wagner et al., 2000).

The second major implication of the results relates to cost-efficiency of habitat and biodiversity monitoring in the context of an Iberian contribution for European or global observation networks. In the coarse-grain landscapes of Mediterranean Spain, as in southern England and elsewhere, ecological heterogeneity is expressed at medium to large spatial scales. 1 km^2 survey areas are therefore needed, as discussed in Firbank et al. (2003), to capture ecological heterogeneity and biological diversity. For these landscapes, the 1 km^2 sample area proposed by the EBONE method has been tested across Europe and elsewhere (Bunce et al., 2011). However, in small-scale landscapes of the Lusitanian zone and many mountain farmland areas, the spatial heterogeneity of abiotic conditions, habitat types and species diversity is expressed at finer scales and across smaller spatial units (e.g. Lomba et al., 2012). The results from the Portuguese sites provide evidence that under such conditions 0.25 km^2 areas are suitable to obtain robust estimates of ecological diversity. Smaller sample units reduce survey effort and contribute to higher cost-efficiency by increasing the total number of samples and the frequency of campaigns.

4.3. Perspectives for a multi-purpose Iberian biodiversity observation network

Besides serving national and regional management needs, the design of an Iberian Biodiversity Observation Network (BON) based on the EBONE framework could have positive implications for reporting on international indicators and on the implementation of conservation policy. The Iberian BON should be implemented in the context of the "Regional BONs" proposed in the GEO BON strategic implementation plan (GEO BON, 2010) and would represent an important contribution from Iberian countries to support the reporting on international indicators e.g. those established in the context of the Convention on Biological Diversity (CBD; Mace and Baillie, 2007) and those proposed for reporting in the European context (SEBI; EEA, 2007). Another key contribution would be for reporting on the implementation of the EU Habitats and Birds Directives in Spain and Portugal, even if complementary surveys would have to be conducted to capture rare species and habitat types. The data to be collected would also boost important research on biodiversity responses to multiple environmental pressures and drivers, from climate change and invasive exotic species (e.g. Vicente et al., 2011) to land use change or environmental policy, by providing field data for model calibration and scenario analysis (e.g. Pereira et al., 2010; Lomba et al., 2012).

In this context, not only a biodiversity and habitats monitoring network will benefit from the implemented standardized protocol, but also other nationally and/or regionally based surveys. A structured sampling program as described above could provide the necessary information on indicators related to habitats and species which could lead to the development of policies for conservation, but it could also provide data valuable for assessing the national implementation of European Directives, e.g. the Water Framework Directive, or for integration with data from agro-environmental surveys, e.g. the Land Use/Cover Area frame statistical Survey (LUCAS) and related sets of indicators (e.g. IRENA; EEA, 2005)

The implementation of an Iberian BON could also benefit from comparable initiatives by being able to integrate results from other surveys related to environmental assessment. Such an integrated development framework would necessarily lead to a standardization of collection procedures and open opportunities for cost-efficiency and integrated environmental analysis. Although there are some important challenges to consider (data integration, different reference systems, different representations and semantics, different ontologies, etc.; e.g. Henry et al., 2008), this integration of systems and the harmonization of processes and tools could represent a landmark for environmental monitoring efforts in the Peninsula and elsewhere.

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